Enhancing Student Engagement and Tennis Skill Acquisition through a Game-Based Learning Approach: A Quasi-Experimental Study in Physical Education

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Abstract. This study investigates the effectiveness of a game-based learning (GBL) approach in improving student engagement and tennis skill acquisition within physical education contexts. Grounded in constructivist learning theory and sport pedagogy frameworks, GBL emphasizes active participation, contextualized practice, and decision-making processes that are essential for motor skill development [1], [2]. A quasi-experimental design employing a one-group pretest–posttest model was utilized, involving 30 undergraduate students enrolled in a physical education program. The intervention was implemented across six structured training sessions integrating modified game scenarios targeting fundamental tennis techniques, including forehand, backhand, and service execution. Student engagement was assessed using a validated observational checklist focusing on behavioral, emotional, and cognitive dimensions, while skill mastery was evaluated through standardized performance tests aligned with tennis competency indicators. Data analysis involved paired sample t-tests to determine statistical significance and normalized gain (N-gain) analysis to assess learning improvement magnitude. The findings demonstrate a statistically significant enhancement in both engagement and skill performance ($p < 0.05$). Mean engagement scores increased from 62.40 (moderate) to 82.75 (high), while tennis performance scores improved from 60.85 to 78.90. The N-gain value of 0.47 indicates a moderate level of effectiveness, suggesting meaningful pedagogical impact. These results align with recent evidence highlighting the role of game-based approaches in fostering intrinsic motivation, improving motor learning efficiency, and enhancing tactical understanding in sports education [3], [4]. From a sport science perspective, the integration of game-based activities facilitates perceptual-motor coupling and contextual interference, which contribute to improved skill retention and transfer [5]. Furthermore, the interactive and student-centered nature of GBL promotes higher engagement levels, thereby supporting more effective learning environments. In conclusion, the game-based approach

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represents a viable and effective instructional strategy for tennis education, offering both pedagogical and performance benefits. It is recommended that educators incorporate GBL frameworks into physical education curricula to optimize student engagement and skill development outcomes.

Keywords: Game-based learning; tennis education; student engagement; skill acquisition; physical education; sport pedagogy; quasi-experimental design.

1 Introduction

Physical education in the 21st century demands pedagogical approaches that extend beyond the development of isolated motor skills to include student engagement, cognitive involvement, and meaningful learning experiences. Within tennis instruction, particularly at the introductory level, teaching practices remain predominantly characterized by technique-oriented drills and teacher-centered delivery models [1]–[3]. While such approaches may contribute to the acquisition of basic technical competencies, they frequently produce passive learning environments in which students exhibit limited engagement, reduced intrinsic motivation, and insufficient understanding of tactical game contexts. Consequently, learning outcomes tend to be fragmented, with weak integration between technical execution and real-game application [3]–[5].

Recent developments in sport pedagogy advocate for learner-centered instructional models that promote active participation and contextualized learning. Among these, game-based learning (GBL) has emerged as a prominent approach, emphasizing the use of modified games to facilitate decision-making, tactical awareness, and skill adaptability [6]–[9]. Grounded in constructivist theory and constraints-led frameworks, GBL enables learners to engage in dynamic problem-solving situations that closely resemble authentic gameplay scenarios. Empirical evidence indicates that such approaches can enhance motivation, improve perceptual-cognitive skills, and support more effective motor learning processes [7], [10].

Despite these advantages, the existing body of research has largely focused on team sports such as soccer, basketball, and handball, where tactical interaction is more explicitly observable [10]–[12]. In contrast, empirical investigations examining the application of game-based approaches in individual sports—particularly tennis—remain relatively scarce. Tennis requires a complex integration of technical precision, anticipatory skills, and situational decision-making, suggesting that GBL may offer substantial pedagogical benefits in this context. However, limited experimental evidence has constrained the generalizability of such claims.

Furthermore, prior studies tend to isolate learning outcomes, with a predominant emphasis on technical skill acquisition while overlooking student engagement as a multidimensional construct encompassing behavioral, emotional, and cognitive dimensions [13], [14]. Engagement plays a critical role in sustaining learning processes and influencing performance outcomes, yet it is seldom examined concurrently with skill mastery within experimental research designs. This gap highlights the need for

more rigorous investigations that simultaneously assess both affective and psychomotor domains using robust methodological approaches.

To address this limitation, the present study adopts a quasi-experimental design employing a one-group pretest–posttest model to evaluate the effectiveness of a game-based learning approach in tennis instruction. A total of 30 undergraduate students participated in a structured intervention consisting of modified game-based activities targeting fundamental tennis techniques, including forehand, backhand, and service execution. This design enables a systematic examination of changes in student engagement and skill performance following the intervention, thereby providing a more comprehensive evaluation of instructional effectiveness.

The novelty of this study lies in two key aspects. First, it integrates an experimental framework within the application of a game-based pedagogical model in tennis, an area that remains underexplored in sport science literature. Second, it concurrently examines student engagement and skill mastery, offering a multidimensional perspective on learning outcomes. By bridging this gap, the study contributes to both theoretical and applied domains of physical education.

The findings are expected to extend the empirical foundation of game-based learning in sport pedagogy, particularly within individual sports contexts. From a practical standpoint, the study provides an evidence-based instructional model that can be adopted by educators to foster active participation, enhance tactical understanding, and improve technical performance in tennis learning environments.

2 Methods

2.1 Research Design

This study adopted a quasi-experimental approach employing a one-group pretest–posttest design to evaluate the effectiveness of a game-based learning (GBL) intervention on student engagement and tennis skill mastery. This design allows for the systematic comparison of participant performance before and after the intervention, thereby enabling the identification of causal trends in learning outcomes within authentic educational settings [1], [2]. Although the absence of a control group limits external validity, this design is widely applied in sport pedagogy research where controlled experimental conditions are difficult to implement [3].

2.2 Participants

The study involved 30 undergraduate students enrolled in a physical education program. A total sampling technique was applied, whereby all accessible participants meeting the inclusion criteria were recruited. The participants were categorized as beginner-level tennis learners, with relatively homogeneous prior exposure to tennis instruction. This homogeneity was considered essential to minimize variability in baseline skill levels and ensure more reliable measurement of intervention effects [4].

2.3 Instruments

Student engagement was assessed using a structured observational instrument encompassing three dimensions: behavioral, emotional, and cognitive engagement. These dimensions reflect established theoretical frameworks in educational psychology and sport pedagogy, where engagement is conceptualized as a multidimensional construct influencing learning outcomes [5], [6].

Table 1. Student Engagement Observation Instrument

No	Dimension	Indicator	Description	Scale (1-5)
1	Behavioral Engagement	Active participation	Student actively participates in all activities	1-5
2	Behavioral Engagement	Task Involvement	Student enganges in game-based learning tasks	1-5
3	Emotional Engagement	Interest	Student demonstrates interest in tennis learning	1-5
4	Emotional Engagement	Enthusiasm	Student shows enthusiasm during activities	1-5
5	Cognitive Engagement	Attention	Student pays attention to instructions	1-5
6	Cognitive Engagement	Learning effort	Student exerts effort in completing learning tasks	1-5

Tennis skill mastery was evaluated using a performance-based assessment focusing on three fundamental components: forehand, backhand, and service. Each component was assessed based on accuracy and technical execution, reflecting core competencies in tennis performance [7].

Table 2. Tennis Skill Performance Assessment

No	Skill Component	Indicator	Assessment Criteria	Score Range
1	Forehand	Accuracy	Ability to direct the ball to a designated target area	0-30
		Technique Execution	Proper stance, grip, and swing mechanics	
2	Backhand	Accuracy	Ability to direct the ball to a designated target area	0-30
		Technique Execution	Correct grip and stroke execution	
3	Service	Accuracy	Successful placement within the service box	0-40
		Technique Execution	Proper toss, swing, and follow-through	

Table 3. Skill Performance Clasification

Score Range	Category
85 – 100	Very Good
70 – 84	Good
55 – 69	Fair
< 55	Poor

2.4 Validity and Reliability

Content validity was established through expert judgment involving three specialists in physical education and sport science. The evaluation confirmed that the instruments adequately represented the constructs of engagement and skill performance.

Construct validity was examined using the Pearson Product–Moment correlation technique. All item correlation coefficients exceeded the critical r-value at $\alpha = 0.05$, indicating that the instrument items were statistically valid [8].

Reliability was assessed using Cronbach's Alpha coefficient. The engagement instrument demonstrated a reliability coefficient of $\alpha = 0.87$, while the skill performance instrument yielded $\alpha = 0.82$, both indicating high internal consistency and measurement reliability [9].

2.5 Data Analysis Techniques

Descriptive statistics were employed to summarize the central tendency and dispersion of engagement and skill performance scores, including mean values and standard deviations.

Data normality was assessed using the Shapiro–Wilk test, where a significance value greater than 0.05 indicates a normal distribution. This test is recommended for small sample sizes and provides robust statistical accuracy [10].

Inferential analysis was conducted using a paired sample t-test to determine the significance of differences between pretest and posttest scores. A significance level of $\alpha = 0.05$ was adopted to evaluate statistical differences [11].

To assess the effectiveness of the intervention, normalized gain (N-gain) analysis was applied. The N-gain index quantifies the magnitude of improvement relative to the maximum possible score, providing a standardized measure of learning effectiveness in educational research [12].

To determine the effectiveness of the intervention using the formula:

$$N\text{-gain} = \frac{Posttest - Pretest}{Maximum\ Score - Pretest}$$

3 Results and Discussion

3.1 Results

The descriptive statistics for student engagement and tennis skill mastery before and after the intervention are presented in Table 4.

Table 4. Descriptive Statistics of Student Engagement and Skill Mastery

Variabel	Pretest Mean	Posttest Mean	Gain	N-Gain	Category
Student Engagement	62.40	82.75	20.35	0.54	Moderate
Skill Mastery	60.85	78.90	18.05	0.46	Moderate

The data indicate a substantial increase in both variables following the implementation of the game-based learning (GBL) intervention. Student engagement improved by 20.35 points, transitioning from a moderate to a high category, while skill mastery increased by 18.05 points, remaining within the moderate improvement range according to normalized gain (N-gain) criteria. The N-gain values (0.54 and 0.46) suggest a meaningful yet not maximal improvement, indicating that the intervention was effective but could yield further gains with extended duration or intensity.

To determine the statistical significance of these improvements, a paired sample t-test was conducted. The results are summarized in Table 5. Paired Sample t-test Results

Table 5. Paired Sample t-test Results

Variabel	t-value	Sig. (p-value)	Interpretation
Student Engagement	8.72	0.000	Significant
Skill Mastery	7.95	0.000	Significant

The p-values for both variables were below the threshold of $\alpha = 0.05$, confirming statistically significant differences between pretest and posttest scores. These findings indicate that the observed improvements are unlikely to be due to random variation and can be attributed to the GBL intervention.

Figure 1 illustrates the comparative increase in mean scores for student engagement and skill mastery between pretest and posttest conditions, demonstrating consistent upward trends across both variables.

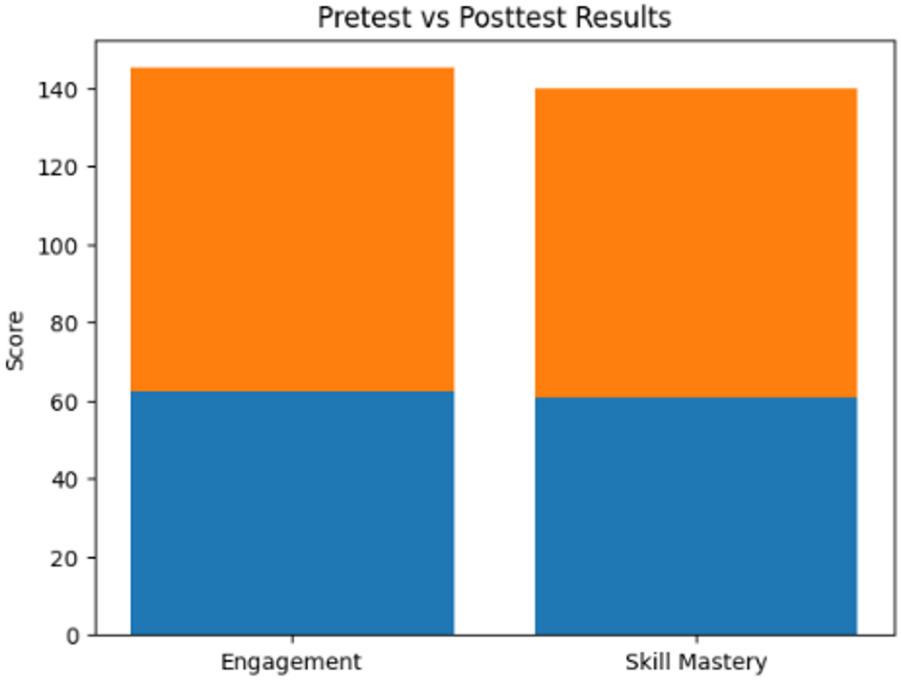

Fig 1. Pretest vs Posttest Results

3.2 Discussion

The results demonstrate that the implementation of a game-based learning approach significantly enhances both student engagement and tennis skill mastery. From a pedagogical perspective, the observed increase in engagement—from a moderate to a

high level—indicates that the learning environment became more interactive, student-centered, and meaningful. This finding is consistent with constructivist learning theory, which posits that knowledge is actively constructed through participation and experiential interaction rather than passive reception [1], [2].

The improvement in engagement can also be interpreted through the lens of motivational theory. Game-based learning incorporates elements such as challenge, competition, and immediate feedback, which are known to stimulate intrinsic motivation and sustain learners' attention [3]. The multidimensional increase across behavioral, emotional, and cognitive engagement supports prior evidence that learner-centered pedagogies foster deeper involvement and persistence in physical education contexts [4], [5].

From a sport science standpoint, the enhancement in tennis skill mastery reflects the effectiveness of contextualized motor learning. Unlike traditional drill-based instruction, GBL situates skill execution within dynamic and game-like scenarios, thereby promoting perceptual-motor coupling and decision-making under realistic constraints [6]. This aligns with the constraints-led approach, which emphasizes the interaction between the learner, task, and environment in shaping skill acquisition [7]. Consequently, students not only improved their technical execution but also developed greater adaptability and tactical awareness.

The moderate N-gain values observed in this study suggest that the intervention produced meaningful improvements, although not at an optimal level. This outcome may be influenced by the relatively short duration of the intervention (six sessions), which may not fully support long-term skill consolidation. Previous research indicates that sustained exposure to game-based approaches is required to achieve higher levels of motor learning and performance transfer [8].

The findings of this study are consistent with prior empirical research demonstrating the effectiveness of game-based approaches, such as Teaching Games for Understanding (TGfU), in enhancing both engagement and performance outcomes [9], [10]. However, this study contributes to the literature by focusing specifically on tennis, an individual sport that has received comparatively less attention than team sports. Furthermore, the integration of both engagement and skill mastery within an experimental framework provides a more comprehensive evaluation of learning effectiveness.

The statistically significant results obtained from the paired sample t-test further strengthen the validity of these findings. The high t-values indicate a strong effect of the intervention, suggesting that the observed improvements are attributable to the structured implementation of game-based learning. This supports the argument that GBL can serve as an evidence-based instructional strategy in tennis education.

Despite these positive outcomes, several limitations should be acknowledged. The use of a one-group pretest–posttest design without a control group restricts the ability to establish causal inference with high external validity. Additionally, the relatively small sample size (n = 30) may limit generalizability. Future research should consider employing randomized controlled designs with larger sample sizes and longer intervention periods to validate and extend these findings. Incorporating biomechanical

or performance-tracking measures may also provide deeper insights into skill development processes.

4 Conclusion

The present study demonstrates that the implementation of a game-based learning (GBL) approach in tennis instruction produces statistically significant improvements in both student engagement and skill mastery. The transition of engagement levels from moderate to high, coupled with a moderate normalized gain (N-gain) and significant pretest–posttest differences ($p < 0.05$), indicates that the intervention effectively enhances learning outcomes across both affective and psychomotor domains. These findings provide empirical support for the effectiveness of GBL as an instructional strategy within physical education settings.

From a sport pedagogy perspective, the effectiveness of GBL can be attributed to its emphasis on contextualized learning, active participation, and decision-making processes that mirror authentic game situations. Such conditions facilitate perceptual-motor integration and adaptive skill execution, which are essential for performance development in tennis [1], [2]. In contrast to traditional drill-based methods, which often isolate technical components, the integration of modified games enables learners to simultaneously develop technical proficiency and tactical awareness within dynamic environments.

Furthermore, the observed increase in student engagement highlights the motivational advantages of GBL. By incorporating elements of challenge, interaction, and immediate feedback, this approach enhances intrinsic motivation and sustains learner involvement throughout the instructional process [3], [4]. The alignment between improved engagement and skill performance underscores the interdependence of affective and psychomotor learning processes in sport education.

Despite these positive outcomes, several limitations should be acknowledged. The use of a one-group quasi-experimental design without a control group restricts the generalizability of the findings, while the relatively small sample size and short intervention duration may limit the extent to which long-term learning effects can be inferred. Future studies are therefore recommended to employ randomized controlled designs, larger participant samples, and extended intervention periods to further validate the effectiveness of GBL in tennis and other individual sports contexts.

In conclusion, this study contributes to the growing body of evidence supporting game-based learning as an effective, evidence-based pedagogical approach in physical education. The findings offer both theoretical and practical implications by demonstrating that GBL can simultaneously enhance engagement, skill acquisition, and learning quality. Accordingly, educators are encouraged to integrate game-based instructional models into tennis teaching practices to optimize student learning experiences and performance outcomes.

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